GLAST LAT SYSTEM SPECIFICATION	Document # LAT-SS-00210-03	Date Effective 23 April 2002
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	Subsystem/Office Calorimeter Subsystem	
Document Title LAT CAL Subsystem Specification - Level IV Specification		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter (CAL) Subsystem L-IV Specification

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes	DCN #
1		Initial Release	
2	13 December 01	Section 15 – Verification Matrix	

Table of Contents

1 PURPOSE

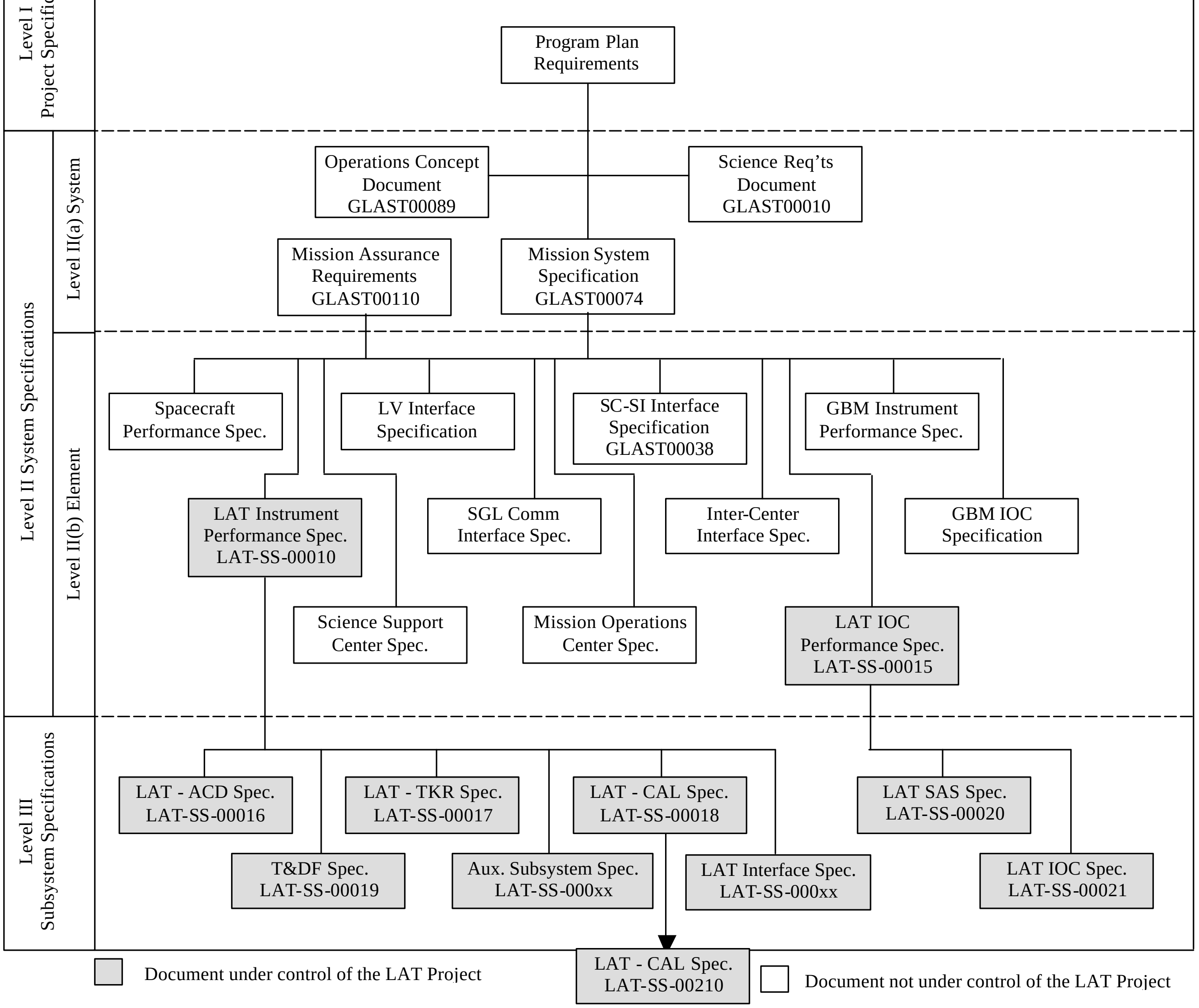
This document defines level IV subsystem requirements for the GLAST Large Area Telescope (LAT) Calorimeter (CAL).

2 SCOPE

This specification captures the GLAST LAT requirements for the CALORIMETER Sub-system. This encompasses the subsystem level requirements and the design requirements for the CAL as derived from the LAT CAL L-III Subsystem Specification. The verification methods of each requirement are identified.

This specification is identified in the specification tree of Figure 2-1.

FIGURE 2-1 SPECIFICATION TREE



DEFINITIONS

2.1 Acronyms

ACD	Anti-Coincidence Detector Subsystem (LAT)
AGN	Active Galactic Nuclei
FOV	Field of View
FWHM	Full Width Half Maximum
GLAST	Gamma-ray Large Area Space Telescope
GN	Ground Network
GRB	Gamma-Ray Burst
IOC	Instrument Operations Center
IRD	Interface Requirements Document
LAT	Large Area Telescope
MC	Monte Carlo
MOC	Mission Operations Center
MSS	Mission System Specification
NRL	Naval Research Laboratory
PI	Principal Investigator
SAS	Science Analysis Software
SDP	Science Data Processing
SI/SC IRD	Science Instrument – Spacecraft Interface Requirements Document
SRD	Science Requirements Document
SSC	Science Support Center
T&DF	Trigger and Data Flow Subsystem (LAT)
TBR	To Be Resolved

2.2 Definitions

γ	Gamma Ray

µsec, µs	Microsecond, 10^{-6} second
A_{eff}	Effective Area
Analysis	A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data.
Analysis platform	toolkit for doing analysis. Examples are IDL and Root.
Arcmin	An arcmin is a measure of arc length. One arcmin is 1/60 degree.
Arcsec	An arcsec is a measure of lengths of arc. One arcsec is 1/60 arcmin
Back Response	Response as measured in the thick layers of the Tracker
Background Rejection	The ability of the instrument to distinguish gamma rays from charged particles.
Backsplash	Secondary particles and photons originating from very high-energy gamma-ray showers in the calorimeter giving unwanted ACD signals.
Beam Test	Test conducted with high energy particle beams
cm	centimeter
Cosmic Ray	Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond.
Dead Time	Time during which the instrument does not sense and/or record gamma ray events during normal operations.
Demonstration	To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
eV	Electron Volt
Field of View	Integral of effective area over solid angle divided by peak effective area.
Front Response	Response as measured in the thin layers of the Tracker
G	unit of gravitational acceleration, g = 9.81 m/s^2
Geometric factor	is Field of View times Effective Area
GeV	Giga Electron Volts. 10^9 eV
Higher Level Processing	Processing of level 1 data into science products. Consists of generating exposure calculations, detecting sources, measuring their spectra, determining their time histories, and locating potential

	counterparts in other astronomical catalogs.
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
Level 0 processing	Processing of raw instrument data. Consists of time-ordering packets, removing incomplete or duplicate packets, and separating housekeeping, calibration, science, and engineering data streams.
Level 1 processing	Processing of level 0 data into level 1 data. Consists of creating a database of reconstructed gamma ray and cosmic ray events.
MeV	Million Electron Volts, 10^6 eV
ph	photons
Point Source Sensitivity	The weakest detectable gamma ray source.
s, sec	seconds
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements
sr	steradian, A steradian is the solid (3D) angle formed when an area on the surface of a sphere is equal to the square of the radius of the sphere. There are 4 Pi steradians in a sphere.
Testing	A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation	Process used to assure the requirement set is complete and consistent, and that each requirement is achievable.
Verification	Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.

3 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the GLAST mission concept and its requirements include the following:

LAT-SS-00018 LAT CAL Subsystem Specification – Level III Specification

GE-00010, "GLAST LAT Performance Specification", August 2000

GLAST00010, "GLAST Science Requirements Document", P.Michelson and N.Gehrels, eds., July 9, 1999.

GLAST00038, "GLAST Science Instrument – Spacecraft Interface Requirements Document", Draft July 14, 2000

GLAST00074, “GLAST Mission System Specification”, Draft, June 30, 2000

GLAST00089, “GLAST Operations Concept”

GLAST00110, “Mission Assurance Requirements (MAR) for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)”, June 9, 2000

CCSDS 102.0-B-3, “Recommendation for Space Data Systems Standards. Packet Telemetry.” October 1989

CCSDS 202.0-B-2, “Recommendation for Space Data Systems Standards. Telecommand, Part 2: Data Routing Service.” October 1989

CCSDS 201.0-B-2, ”Recommendation for Space Data Systems Standards. Packet Telecommand, Part 1: Channel Service.”

CCSDS 201.0-B-1, ”Recommendation for Space Data Systems Standards. Packet Telecommand, Part 2.1: Command Operation Procedures.”

NPD 8010.2B, “NASA Policy Directive, Use of Metric System of Measurement in NASA Programs”

“Recommended Priorities for NASA’s Gamma Ray Astronomy Program 1996-2010”, Report of the Gamma Ray Astronomy Program Working Group, April 1997.

“The Evolving Universe: Structure and Evolution of the Universe Roadmap 2000 - 2020”, roadmap document for the SEU theme, NASA Office of Space Science, June 1997.

“The Space Science Enterprise Strategic Plan: Origins, Evolution, and Destiny of the Cosmos and Life”, NASA Office of Space Science, November 1997.

“Gamma Ray Large Area Space Telescope Instrument Technology Development Program”, NRA 98-217-02, NASA Office of Space Science, January 16, 1998.

“GLAST Large Area Telescope Flight Investigation: An Astro-Particle Physics Partnership Exploring the High-Energy Universe”, proposal to NASA, P. Michelson, PI, November, 1999.

4 GLAST LAT Instrument Concept

The LAT science instrument (SI) consists of an Anticoincidence Device (ACD), a silicon-strip detector tracker (TKR), a hodoscopic CsI calorimeter (CAL), and a Trigger and Dataflow system (T&DF). The principal purpose of the SI is to measure the incidence direction, energy and time of cosmic gamma rays. The measurements are streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers.

4.1 Calorimeter Sub-system

The CAL provides the energy measurement of incident photons and background particles. These measurements, along with the information in the TKR, are used to reconstruct the energy of the incident photons. These CAL measurements are also critical to the background particle identification and rejection. The CAL responds to T&DF requests by digitizing the energy loss in the CAL and outputs the data to the dataflow system. The CAL also provides fast signals to the T&DF system that report significant energy depositions in CAL. The T&DF system analyzes these fast signals to form requests for data readout of GLAST.

The CAL subsystem consists of a 4×4 array of identical modules. Each module is a hodoscopic array of CsI scintillation crystals and associated readout electronics. Figure 1 shows an expanded view of a single calorimeter module.

4.2 Instrument Responsibilities

The Calorimeter is being developed by a collaboration led by the Naval Research Laboratory (NRL). NRL is responsible for managing the development of the calorimeter subsystem, including

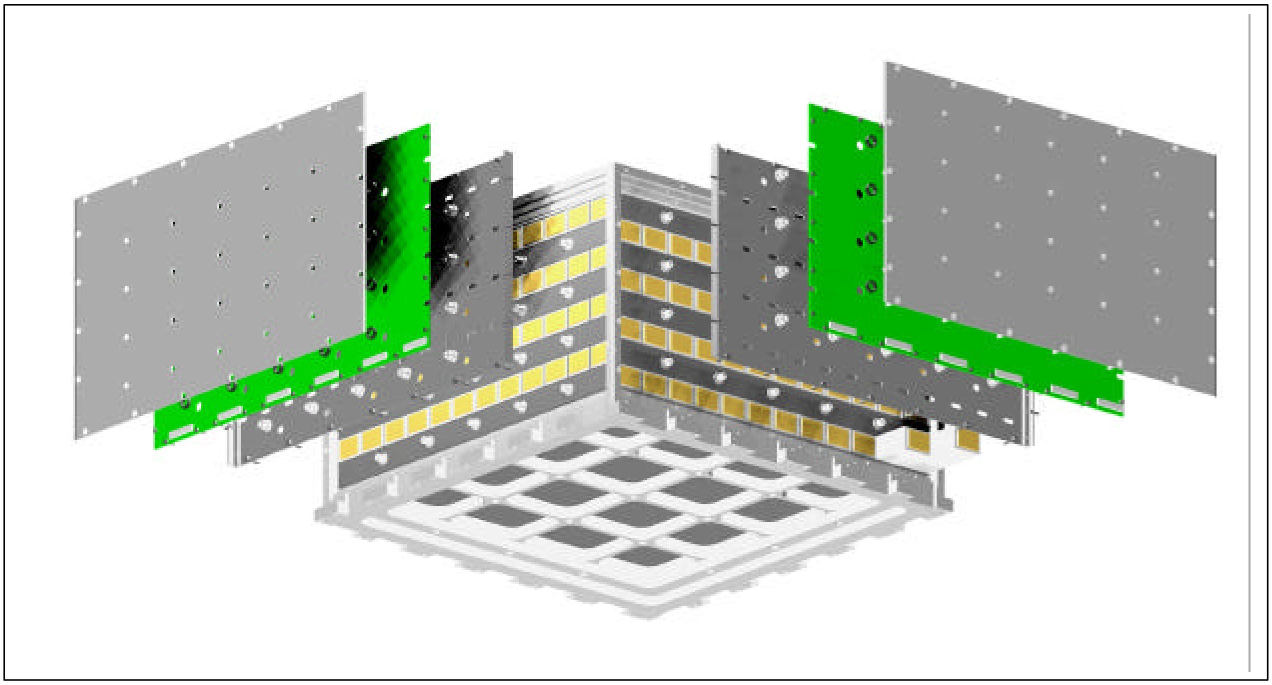


Figure 1. Calorimeter module concept.

Calorimeter design, fabrications, test, and calibration. NRL is responsible to deliver the Calorimeter Modules to SU-SLAC. The responsibilities of the French parties are listed in section 8.4 of the MoA (LAT-MD-XXXXX). The Swedish groups are responsible for the procurement and acceptance testing of the Thallium-doped Cesium Iodide (CsI) as described in MoA document number LAT-MD-00081-D3.

a) The institutions responsible for the research teams taking part in the GLAST LAT instrument and forming *the Collaboration*, are hereinafter collectively referred to as *the Collaborating Institutions.* The French institutions involved in the GLAST LAT Calorimeter are Commissariat à l'Energie Atomique / Direction des Sciences de la Matière / Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée (CEA/DSM/DAPNIA) and Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) representing the three following laboratories: PCC of Collège de France, LPNHE of Ecole Polytechnique and CENBG of Université de Bordeaux. The U.S. institutions involved in the GLAST LAT Calorimeter are the Naval Research Laboratory (NRL) and the Stanford Linear Accelerator Center (SU-SLAC).

b) SU-SLAC, operated by Stanford University (hereinafter Stanford), under contract DE-AC03-76SF00515 with the U.S. Department of Energy (DOE), is responsible for management and integration of the LAT instrument. SU-SLAC is the responsible party accountable to the U.S. Department of Energy for the program execution. Stanford University is responsible for the appropriate expenditure of U.S. Government funds.

5 Calorimeter Subsystem Requirements

5.1 General Scientific Performance

5.1.1 Energy Range

[Derived from LAT SS-00010 5.2.1]

The calorimeter subsystem shall support LAT energy measurements of incident photons and charged particles in the energy range 20 MeV to 300 GeV.

5.1.2 Depth of Calorimetry.

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall have an active depth of greater than 8.4 (TBR) radiation lengths of CsI for normally incident particles. The calorimeter shall have adequate depth to contain most of the energy of the gamma-ray showers

5.1.3 Energy Resolution

The energy resolution shall allow for the measurement of spectral breaks already observed or theoretically predicted from celestial sources.

5.1.3.1 Active Area

[Derived from LAT SS-00010 5.2.2]

The calorimeter subsystem shall provide a projected CsI area of greater than 16800 cm^2 (TBR) for normally incident particles.

5.1.3.2 Passive Material

[Derived from LAT SS-00010 5.2.2]

Passive material in a calorimeter module (everything not CsI) shall represent no more than 16% (TBR) of the total mass of the module.

5.1.3.3 On-axis Energy Resolution – Low Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% (TBR) for normal incidence photons for energies in the 20 – 100 MeV range that interact in the calorimeter only. The energy resolution (1σ) shall be less than 10% for photons for energies in the 100 MeV – 10 GeV range.

Note: Low energy measurements require contributing TKR energy loss measurement to achieve specified resolution.

5.1.3.4 On-axis Energy Resolution – High Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% for photons, with on-axis incidence, for energies in the 10 – 300 GeV range.

5.1.3.5 Off-axis Energy Resolution – High Energies

[SRD Table 1, #7]

The energy resolution (1σ) shall be less than 6% for photons, with angles of incidence >60 degrees off axis, for energies greater than 10 GeV. The effective area for these off-axis measurements with this energy resolution is expected to be 10 – 20% of the on-axis effective area at energies greater than 10 GeV.

The goal is less than 3%.

5.1.4 Hodoscopic Calorimetry

The calorimeter shall provide imaging capability or physical segmentation to allow the correlation of events in the tracker with energy depositions in the calorimeter.

5.2 Modular Calorimeter Subsystem

5.2.1 Components

The calorimeter subsystem shall consist of a 4×4 array of identical modules.

5.2.2 Mounting

The calorimeter modules shall be mounted inside the grid matrix of the LAT GRID subsystem.

5.2.3 Structure

The base of the calorimeter modules shall support the mechanical, thermal and electrical interfaces of the LAT T&DF, ACD and power system components.

5.2.4 Hodoscopic

The calorimeter modules shall be hodoscopic arrays of CsI(Tl) scintillation crystals: eight (8) layers of twelve (12) CsI(Tl) scintillation crystals.

5.2.5 PIN Photodiodes

PIN photodiodes shall view each end of the CsI scintillation crystals for measurement of the energy depositions in the crystals.

5.2.6 Crystals

The CsI crystals shall be processed such that the measurements by the PIN photodiodes at the ends of a crystal provide a measurement of the longitudinal position of the energy deposition in the crystal.

5.2.7 Electronics

Each calorimeter module shall include analog and digital readout electronics (AFEE) on the four vertical faces at the ends of the CsI crystal array.

5.3 Calorimeter Module Organization

5.3.1 Module Components

The major components of a calorimeter module shall be a mechanical structure, an array of ninety-six CsI(Tl) detector elements and four analog front end electronics (AFEE) printed wire assemblies.

5.3.2 Module Energy Measurement Range

The energy measurement of the calorimeter modules is defined by the performance at the single crystal level and the muon energy resolution.

5.3.2.1 Single CsI Crystal Energy Measurement Range

The energy measurement range for each of the CsI scintillation crystals shall include the range from 5 MeV to 100 GeV.

The goal is to achieve a low energy threshold of 1 MeV.

5.3.2.2 Muon Energy Resolution

The energy resolution (1 sigma) shall be <4% (TBR) for sea-level muons within 6 cm of the central point of the crystal. This measurement shall be deduced from the width of the distribution of the difference in signals of the two large diodes, as given in the following expression: sigma(mu) = sigma(Diff) / sqrt(2), where sigma(mu) is the deduced energy resolution for muons as measured in a single large diode and sigma(Diff) is the measured rms of the distribution of differences P-M in the signal from the large diodes of the Plus (P) and Minus (M) faces. This test may be performed with laboratory electronics of arbitrarily low noise performance.

5.3.3 Command and Data Interface

5.3.3.1 Communication

The calorimeter electronics shall communicate with the Trigger and Data Flow (T&DF) subsystem using LAT standard communications protocols.

5.3.3.2 Data Format

Serial data from the readout electronics shall be merged into a serial message by a tower electronics module (TEM) mounted on the base plate of each module for transfer to the T&DF subsystem.

5.3.3.3 Data Collection

The TEM shall process trigger requests and collect rate and housekeeping monitoring from the CAL AFEE and distribute commands from the T&DF to the AFEE.

5.3.4 Measurement Dead Time

[LAT SS-00010 5.2.13]

The dead time associated with the capture and measurement of the energy depositions shall be less than 100 μsec. The goal is less than 20 μsec.

5.3.5 Overload Recovery

[Derived from LAT SS-00010 5.2.2, 5.2.13]

The calorimeter electronics shall be capable of recovery from a x1000 overload within 500 μsec. Recovery is defined as below the measurement readout (zero suppression) threshold.

5.3.6 Low Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) low-energy trigger signal to the LAT trigger system with a detection efficiency of greater than 90% (TBR) for 1 GeV gamma rays entering the calorimeter from the LAT field of view with a trajectory which traverses at least 6 RL of CsI.

5.3.7 High Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) high-energy trigger signal with a detection efficiency of greater than 90% for 20 GeV gamma rays entering the calorimeter from the LAT field of view that deposit at least 10 GeV in the CsI of the calorimeter.

5.3.8 Operating Modes

[Derived from LAT SS-00010 5.3.5]

The calorimeter shall be capable of operating continuously throughout the orbit. Operating through traversals of the South Atlantic Anomaly shall not damage the calorimeter but, because of the excessive background rates, the acquired data shall not be required to meet performance specifications.

5.3.9 Module Geometric Area

Each calorimeter module shall provide a projected CsI area of greater than 1050 cm^2 (TBR). for normally incident particles.

5.3.10 Module Mass

The mass of each calorimeter module shall not exceed 93.25 kg ± TBR kg. (**TBR**)

[COMMENT: SRR mass estimate plus 10% of ANSI/AIAA estimated reserves]

5.3.11 Module Power

The power consumption of each calorimeter module, excluding conditioning, shall not exceed 5.6875 W **(TBR).** Table 1 summarizes power allocation by mission mode.

[COMMENT: Lehman review power adjusted for 80% efficiency of converters]

Table 1. Power allocation by mission mode - TBD

Pre-launch	Launch	Initial Acquisition	Science-ops	Safe	Survival		

5.4 Environmental

The CAL shall be capable of normal operation after being subjected to the environmental conditions given in LAT-SS-00010, Section 5.3.12, Environmental.

6 Crystal Detector Elements

The Crystal Detector Elements (CDE) include CsI(Tl) crystals, PIN Photodiodes, optical reflective wrap, and PIN interconnection to the AFEE PCB.

6.1 CDE Organization

6.1.1 Module Contents

Each calorimeter module shall contain 96 CDE.

6.1.2 CDE Crystal

The CDE shall contain a CsI(Tl) crystal shaped as a rectangular parallelepiped with beveled edges and its surfaces treated to control scintillation light yield at the two ends.

6.1.2.1 Wrap

The CDE shall contain an optical wrap surrounding the CsI crystal to provide the required optical performance (See Requirement 6.2).6.1.3 CDE Photodiode

The CDE shall have a PIN photodiode assembly bonded to each end of the CsI crystal.

6.1.4 Cable

A flexible printed circuit cable shall be attached to each PIN photodiode to provide electrical connections with the analog front end electronics board (AFEE).

6.2 CDE Optical Performance

6.2.1 Large Diode Light Yield

The light yield measured by the large PIN photodiode shall be 5000 e-/MeV for energy depositions at the center of the CsI crystal (beginning of life, room temperature (20 – 25 deg C), measurement techniques as specified in LAT-TD-00381-01).

6.2.2 Small Diode Light Yield

The light yield measured by the small PIN photodiode shall be 800 e-/MeV for energy depositions at the center of the CsI crystal (beginning of life, room temperature (20-25 deg C), measurement techniques as specified in LAT-TD-00381-01).

6.2.3 Light Asymmetry with PIN Photodiodes

The change in light asymmetry measure shall be between 0.24 and 0.48 for muon or thorium energy depositions at ± 12 cm from the center of the crystal. The asymmetry measure is defined as the ratio (P-M)/(P+M), where P = signal in the large diode at the "plus" end and M = signal in the large diode at the "minus" end.

This requirement shall be verified on all CDEs. The required range is consistent with the crystal light tapering specification.

6.2.4 Surface Treatment

The crystal end faces shall be roughened in a random pattern to increase the strength of the bond with the photodiode assembly. The long faces shall be treated to achieve the light asymmetry specification (6.2.3) with the specified wrapping technique (6.2.5).

6.2.5 Wrapping Technique

The crystal shall be wrapped with VM 2000 reflective film. The wrap shall be sufficiently tight that the completed CDE can be inserted into its cell within the mechanical structure. The wrap shall not extend past the ends of the crystal, so that it does not interfere with the fixturing of the CDE within its cell. The ends of the crystal shall not be covered with the wrap.

6.2.6 Temperature Effects

The CDE shall meet requirements over the qualification temperature range described in section 8.1.

6.2.7 Radiation Effects

6.3 Spatial Resolution of Energy Deposition

The calorimeter shall be capable of positioning a Minimum Ionizing energy deposition to less than 1.5 cm (1 σ) (TBR).

6.4 CsI(Tl) Crystal Requirements

Full performance specification for the CDE CsI crystals is in LAT-DS-00095 CsI Cyrstal Specification. The information in this section is for reference only.

6.4.1 Crystal Geometry

The CsI (Tl) crystals shall be rectangular parallelpipeds with a chamfer on the edges of the long dimension. Figure 1 of LAT-DS-00096 shows the mechanical configuration and tolerances for the crystals.

6.4.2 Dimensions

Overall dimensions (mm) of the CsI crystals at 20° C shall be:

Length	333.0 mm
Height	19.9 mm
Width	26.7 mm

6.4.3 Tolerances

The tolerance on dimensions (mm) shall be:

Length	+ 0.0, –0.6 mm
Height and Width	+ 0.0, –0.4 mm

6.4.4 Chamfer

The four 333 mm edges of the crystal shall have a chamfer.

Chamfer length:	0.7 mm, tolerance ± 0.20
Chamfer angle:	45°, tolerance ± 5

6.4.5 Light Yield

The signals from each 5 cm diameter photomultiplier tube (PMT) in contact with the two ends of a crystal log shall have a FWHM (Full Width Half Maximum) of less than or equal to 13% with the source at any of eleven (11) evenly spaced points starting 2 cm from one end and finishing 2 cm from the other end of the log. The absolute light yield of the array of crystals shall not vary from crystal to crystal by more than10% from the mean value. This shall be determined by using average of the light yields measured at the eleven sampling points identified in section 6.2.1 of LAT-DS-00095. This average light yield, when corrected for instrumental effects of photo-multiplier gain, shall be the same for all crystals to within 10%.

6.4.6 Light Yield Tapering

The CsI crystals shall be processed so that the scintillation light is tapered with position. The tapering shall be monotonic along the crystal and such that with the source 2 cm from one end the light collected at the far end is 60 ± 10 % of the light collected by the PMT close to the source. The tapering shall be determined using PMTs exposed to the full crystal end faces.

6.4.7 Radiation Hardness

Radiation environment (total radiation dose) shall not reduce light output from the CsI crystals by more than 50% at EOL. After radiation with 10 krad gamma-rays from a Cobalt-60 source, the light yield shall not be reduced by more than 50%.

6.5 PIN Photodiodes

6.5.1 Active Area

The PIN assembly shall hold two PIN photodiodes with a factor of 6 ratio of active areas.

6.5.2 Spectral Response

The photodiodes shall have spectral response compatible with the scintillation spectrum of CsI(Tl).

6.5.3 Photo Sensitivity

The photodiodes shall have photo sensitivity greater than 0.33 A/W at 540 nm.

6.5.4 Dark Current

The photodiodes shall have dark current of less than 10 nA for the large diode and 3.0 nAfor the small diode, at 20 °C.

6.5.5 Terminal Capacitance

The photodiodes shall have terminal capacitance of less than 90 pFfor the large diode and 15 pFfor the small diode at 1 MHz with 70 V reverse bias. (Note: Diode spec states 100pf for large, Ampe provided 90pf)

6.5.6 Full Depletion

The photodiodes shall have full depletion at 70V

(Note: Ampe says N/A, not a source of significant noise) (Note: Ampe says N/A, no longer issue with separate silicon for each diode)

6.5.7 Physical Dimensions

The photodiode carrier shall be 22.3 (±0.2) mm × 15.0 (±0.2) mm × 1.8 (±0.2) mm.

6.5.8 Active Areas

The small PIN photodiode shall have active area greater than 25 mm^2.

The large PIN photodiode shall have active area greater than 150 mm^2.

7 Mechanical / Structure

7.1 CAL Module MechanicalRequirements

7.1.1 Calorimeter Mass

Total mass of a calorimeter module shall not exceed 93.25 kg ± TBR kg. (**TBR**)

7.1.2 Geometry

The calorimeter module shall comply with the geometry specified in Table 2. The total height of the calorimeter and its mechanical mounting structure shall not exceed 223.8 mm.

Table 2. Calorimeter Module Geometry Summary

CAL Module	Width	Height	Length	Comments
GRID bay nominal dimensions	366.500			
CAL Module stay-clear	364.000	224.300		
CAL Module nominal dimensions	363.000	223.800		
CsI Logs (W x H x L)	26.700	19.900	333.000	Max dims per spec
Bottom flange thickness		15.000		
C.G. of Cal off of CAL Bottom flange		TBD		

Note: Dimensions are in millimeters.

(Note: Stated earlier in document)

7.1.3 Mechanical Interfaces

The CAL module structure shall provide the mechanical interface to the LAT grid as specified in ICD LAT-SS-00238.

The CAL module structure shall provide the nominal positioning, support and mounting interfaces for all subsystem components.

The CAL module structure shall support the Power Supply module and TEM as specified in ICD TBD.

7.1.5 Venting Requirements

The CAL structure shall vent downward, past the bottom plate, not up into the volume between the TKR and the CAL as described in ICD LAT-SS-00238.

7.1.6 Purging Requirements

Purging with dry nitrogen shall be required if the relative humidity of the environment exceeds 50%. (RH of 50% from CC Plan, LAT-MD-00228)

7.2 CAL Module Structural Requirements

The CAL structure shall provide and maintain the positional integrity of all components that it supports. The structure shall maintain the operational stability of the positions of all instrument components under load.

7.2.1 Structural Stiffness

The CAL structure baseplate is integral to the strength and stability of the LAT GRID. The mechanical structure shall provide a minimum fundamental frequency greater than 100 Hz to a CAL module, isolated from other systems.

7.2.2 Distortion Under Load

7.2.2.1 Distortion Under Static Load

The CAL mechanical structure shall be able to withstand the different load events without yielding, failing or exhibiting deformations that can influence the performance of the CAL modules or any other system or sub-system. Any point of the mechanical structure shall not displace by more than 0.5mm under a +/-12 g static load, applied along X or Y axis independently, to avoid interaction with the grid walls. Any point of the top of the mechanical structure shall not displace by more than 0.5 mm under a +/- 12 g static load applied along Z axis. To minimize mechanical loads on the TEM boxes, attached below the CAL modules, no point of the bottom plate of the mechanical structure shall displace by more than 0.5mm under a +/- 12 g static load applied along the Z axis.

7.2.2.2 Distortion Under Dynamic Load

The CAL mechanical structure shall be stiff enough in the X and Y directions to keep the difference between the RMS displacements between any two points of the side panels below 0.25 mm, under random vibration with qualification levels. The mechanical structure shall be stiff enough in the Z direction to keep the difference between the RMS displacements between any two points of the top of the structure below 0.5 mm, under random Vibration with qualification levels. The mechanical structure shall be stiff enough in the Z direction to keep the difference between the RMS displacements between any two points of the bottom plate below 0.25 mm, under random vibration with qualification levels. The levels for random vibration are defined in table 3.7-3 of LAT-SS-00241-D2.

7.2.2.3 Distortion Under Thermal Load

Over a temperature change of 10 degrees C, the mechanical structure shall not distort more than:

0.25 mm between any two points of the side panels

0.5 mm between any two points of the top of the structure

0.25 mm between any two points of the bottom plate

8 Thermal

8.1 Temperature Ranges

The LAT thermal control system shall maintain the CAL components within the operating, test and survival temperatures shown in Table 3.8-1 of LAT-SS-00241-D2. This table is shown below for reference. (Note: Assembly in Level II is 15-25).

	Environmental thermal loads					
	Assembly Integration	Storage Transport	On LV	Launch	Operational	Survival
T_{max} qualif. Test (1)					35 °C	50 °C
T_{max} design accept	25 °C	40 °C	26.7 °C	30 °C	25 °C	40 °C
T_{min} design accept	20 °C	0 °C	12.8 °C	0 °C	-10 °C	-20 °C
T_{min} qualif. Test (1)					-20 °C	-30 °C
Nbr of cycles					120	120
dT/dt_{max} (2)					5 °C/hr	5 °C/hr

(1) Test temperature set at 10 °C higher than maximum design temperature and 10 °C lower than minimum design temperature, per GEVS-SE rev A
(2) Maximum time rate of change of temperature

8.2 Temperature Monitoring

The temperature of each AFEE boards shall be monitored by a sensor with an accuracy of ± 0.5C. The temperature of the top plate and bottom plate of the calorimeter shall also be monitored by separate temperature sensors with the same accuracy. There shall therefore be 6 sensors per calorimeter module, or 96 sensors for the entire calorimeter. These sensors shall be read out once per minute. The housekeeping software shall monitor the temperature of the 96 sensors and issue a warning if any sensor goes out of a TBD range. If any sensor goes out of the broader TBD range, the power to the calorimeter module associated with the sensor will be turned off and a red flag issued for the instrument.

9 Analog Front End Electronics

The calorimeter module contains four (4) analog front end electronics (AFEE) printed wiring assemblies, one mounted on each vertical face and attached to the PIN photodiodes on that face. The main components of the AFEE are the GLAST Calorimeter Front End (GCFE) analog ASICs, the analog to digital converters (ADCs) and the GLAST Calorimeter Readout Controller (GCRC) ASICs

9.1 GCFE

The basic functions of the GCFE include charge-sensitive amplification, shaping, multi-range post-amplification, , trigger function, track&hold function, and auto-range selection. The key challenges for the ASIC are the large dynamic range and low power dissipation.

The GCFE shall perform spectroscopic measurements over a range from 0.4 MeV to 100 GeV. Each GCFE ASIC shall service one crystal end.

The dynamic range shall be divided into two independent signal chains, one for the low energy range, one for the high energy range.

9.1.1 Signal Characteristics

The maximum charge delivered to the input of the GCFE ASIC in each gain range shall comply with the following table, under the assumption of the nominal values for light yield in the photodioes (Requirements 6.2.1 and 6.2.2) and amplifier ranges (Requirements 9.1.3.6 to 9.1.3.9).

Range	pC at GCFE Input
LEX8	.16
LEX1	1.3
HEX8	1.6
HEX1	13

9.1.2 Low Energy Signal Chain

9.1.2.1 Low Energy Range

A large area (~150 mm^2) PIN photodiode provides the input signal for the low energy range charge amplifier. The low energy charge amplifier shall process energy depositions in the 2 MeV to 1.6 GeV range. The characteristics of the inputs to the low energy range are summarized in Table 9.3.

Table 9.3. Characteristics of GLAST dual PIN photodiode.

Diode	Area (mm^2)	Cap (pF)	Leakage (20 °C)	Signal e/MeV
Low Energy	150	< 90	< 10 nA	5000
High Energy	25	< 15	< 3 nA	800

9.1.2.2 Low Energy Charge Sensitivity

The low energy range amplifier shall receive a charge of ~ 5000 e$^-$/MeV (TBR) with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 9.4.

Table 9.4. Relative time constants in CsI(Tl)

Exponential Time Constant	Total Charge %
25 ns	2%
700 ns	60%
3.5 μs	40%

9.1.2.3 Low Energy Input Capacitance

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 90 pF (TBR). (Note: Diode spec says 100, Ampe provided 90)

9.1.2.4 Low Energy Input Dark Current

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 10 nA (TBR) at a temperature of 20 °C.

9.1.2.5 Low Energy Overload Recovery

The low energy front end shall recover from a ×1000 overload within 100 µsec (TBR). Recovery is defined as signal amplitude below the accept or zero-suppression threshold.

9.1.2.6 Low Energy Gain Adjust

The gain of the low energy channels shall be adjustable by at least a factor of 2 in steps of approximately 10% – 25%.

9.1.3 High Energy Signal Chain

9.1.3.1 High Energy Range

A smaller area (~25 mm^2) PIN photodiode provides the input signal for the high energy range charge amplifier. The high energy charge amplifier shall process energy depositions in the 100 MeV to 100 GeV range. The characteristics of the inputs to the high energy range are summarized in Table 9.3.

9.1.3.2 High Energy Charge Sensitivity

The high energy range amplifier shall receive a charge of ~ 800 e$^-$/MeV (TBR) with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 9.4.

9.1.3.3 High Energy Input Capacitance

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 15 pF (TBR).

9.1.3.4 High Energy Input Dark Current

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 3 nA (TBR) at a temperature of 20 °C.

9.1.3.5 High Energy Gain Adjust

The gain of the high energy channels shall be adjustable by at least a factor of 2 in steps of approximately 10% – 25%. An additional gain setting shall be used for ground aliveness testing.

9.1.4 Shaping Amplifiers

The outputs of the charge sensitive preamps shall be shaped with two differing time constants, fast shaping for trigger discriminators and a slower shaping for energy measurements. The slow shaped signals of each charge amplifier are are each divided into two energy domains.

9.1.4.1 Low Energy Fast Shaper (FLE) Peaking

The low energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

9.1.4.2 Low Energy Fast Shaper Energy Range

The low energy fast shaping amplifier shall support the lowest ~25% of low energy range, i.e. nominally 400 MeV maximum energy.

9.1.4.3 High Energy Fast Shaper (FHE) Peaking

The high energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

9.1.4.4 High Energy Fast Shaper Energy Range

The high energy fast shaping amplifier shall support the entire low energy range, i.e. nominally 100 GeV maximum energy.

9.1.4.5 Low Energy Slow Shapers (SLE) Peaking

The low energy fast shaped signals shall peak at 3.5 ± 0.5 μsec. All ASICs shall have the same peaking time $\pm$ 0.2 μsec.

9.1.4.6 Low Energy X1 (LEX1) Amplifier

The LEX1 amplifier of the low energy channel shall process the entire low energy charge amplifier range, ie. nominally 1.6 GeV maximum energy.

9.1.4.7 Low Energy X8 (LEX8) Amplifier

The LEX8 amplifier of the low energy channel shall process the lowest eighth of the low energy charge amplifier range, ie. nominally 200 MeV maximum energy.

9.1.4.8 High Energy X1 (HEX1) Amplifier

The HEX1 amplifier of the high energy channel shall process the entire high energy charge amplifier range, ie. nominally 100 GeV maximum energy.

9.1.4.9 High Energy X8 (HEX8) Amplifier

The HEX8 amplifier of the high energy channel shall process the lowest eighth of the high energy charge amplifier range, ie. nominally 12.5 GeV maximum energy.

9.1.5 Track & Hold

Each of the four slow shaped amplifiers (LEX8, LEX1, HEX8, HEX1) shall have track and hold (T&H) circuits designed to hold the peak amplitude of the shaped outputs for amplitude measurements using external ADCs. The timing of the hold signal to capture the peak shall be controlled externally.

9.1.5.1 T&H Tracking

When the hold signal is not active, the T&H circuit shall track the amplitude of the shaped input signal. Thus, adjustment of the hold signal timing relative to the energy deposition shall permit mapping of the pulse shape of the shaper output.

9.1.5.2 T&H Hold

The T&H circuit shall respond to an externally generated hold signal by capturing the amplitude of the shaped signal at the time of the hold. Hold aperture time shall be less than 50 nsec.

9.1.5.3 T&H Droop

The T&H circuit shall be capable of holding a constant signal amplitude for > 100 μsec with less than 0.1% droop for a signal amplitude dynamic range of 500 (TBR).

9.1.6 Non-Linearity

The maximum non-linearity in each of the four ranges: LEX8, LEX1, HEX8 and HEX 1 shall be 1 % of full range.

9.1.7 Analog Multiplexer

An analog multiplexer shall present one of the four T&H signals to an output buffer for external amplitude measurements with an ADC. The analog multiplexer shall be controlled by energy range selection logic as described in 9.1.7.

9.1.8 Output Buffer

An output buffer shall accept the output of the analog multiplexer and drive the load of an external ADC.

9.1.8.1 Output Buffer Range Adjust

The external buffer shall adjust the voltage range of the analog multiplexer to match the input voltage range of the external ADC.

9.1.9 Energy Range Selection

Energy range selection logic shall control which of the four T&H energy ranges is selected in the analog multiplexer and presented to the output for digitization by the ADC.

9.1.9.1 Range Selection Discriminators

Range selection discriminators shall test the output of the four T&H ranges to determine which of the ranges have been saturated by the energy deposition in the crystal. Saturation is defined as the amplitude at which the input signal enters a non-linear region.

9.1.9.2 Range Selection Readout

The results of the range selection logic, i.e. the multiplexer setting, shall be transmitted to external logic for inclusion in the event readout with the associated ADC value.

9.1.9.3 Auto Range Selection

In auto range selection mode, the range selection discriminators shall be tested to select the T&H output with the lowest energy range (highest gain) that is not saturated and set the analog multiplexer to this T&H output.

9.1.9.4 Commanded Range Selection

In commanded range selection, the selection logic shall use a pre-loaded (via command input) range and set the multiplexer to that T&H output.

9.1.9.5 Sequential Range Selection

In either the auto range or commanded range selection mode, it shall be possible to sample all four T&H outputs in sequence. The sequence shall start at the autoranged or commanded range and increment (modulo 4) through the four ranges. The increasing order shall be LEX8, LEX1, HEX8 and HEX1.

9.1.10 Zero Suppression or Measurement Accept Readout

9.1.10.1 Accept Discriminator

The amplitude of the LEX8 output shall be compared with a programmable threshold – the accept lower level discriminator – to identify CsI crystals with measureable energy depositions. This crystal-accept signal shall be transmitted to external logic for determination of crystals to be included in the event readout message.

9.1.10.2 Accept Discriminator Adjustment

The accept discriminator level shall be adjustable by command to the ASIC with adjustment resolution of ~ 0.25 MeV over the lowest approximately 10% of the LEX8 energy range.

9.1.11 Trigger Discriminator and Logic

The outputs of the two 0.5 μsec shaping amplifiers (FHE and FLE) are connected to discriminators. The two outputs of the trigger discriminator logic are provided to external logic which forms the calorimeter trigger request inputs to the GLAST trigger system.

9.1.11.1 Trigger Jitter

The variation in time of the leading edge of the trigger output from the time of energy deposition shall be less than ± 0.2 μsec.

9.1.11.2 Trigger Enables

Each of the two trigger signals shall be individually enabled or disabled by command input to the ASIC.

9.1.11.3 Low Energy Trigger Discriminator Adjustment

The low energy trigger (FLE) discriminator level shall be adjustable by command input to DACs inside the ASIC. Two adjustment ranges shall be provided: lowest energies (< ~60 MeV) with ~ 1 MeV resolution and moderate energies (< ~ 400 MeV) with ~ 5 MeV resolution.

9.1.11.4 High Energy Trigger Discriminator Adjustment

The high energy trigger discriminator level shall be individually adjustable by command input to DACs inside the ASIC. The range of adjustment shall include the lowest ~25% of the high energy charge amplifier range (< ~ 25 GeV) and have ~ 200 MeV resolution.

9.1.12 Calibration System

The GCFE ASIC shall accept a precision calibration voltage from an external DAC as a reference voltage for a calibration charge injection system.

9.1.12.1 Calibration Range

The test charge injection system shall be capable of testing the entire dynamic range of the GCFE ASIC.

9.1.12.2 Charge Shaping

The charge injection system shall provide input signals to the charge amplifier with time characteristics similar to the CsI light collection.

9.1.12.3 Charge Injection

External signals shall cause the injection of charge into the charge amplifiers. Commandable configuration logic shall cause the injection to occur into either or both of the low energy and high energy charge amplifiers.

9.1.12.4 Test Gain on High Energy Charge Amplifier

The high energy charge amplifier shall provide a test gain to be used in ground aliveness tests with cosmic muons. The test gain shall increase the nominal gain by a factor of approximately 10. The test gain configuration is pre-selected by command input to the ASIC.

9.1.13 Configuration Control

The GCFE ASIC operating configuration shall be selected by commands received via serial command system that is compatible with GLAST standard command protocols.

9.1.13.1 Command Address

Each GCFE ASIC shall respond to its own command address, which shall be programmed via input address pins.

9.1.13.2 Command Functions

The GCFE shall decode and recognize predefined command functions and internally route associated command function data to the appropriate configuration register.

9.1.13.3 Configuration Readback

The GCFE shall be capable of reporting its operating configuration to the external data system when requested via configuration readback command requests.

9.1.14 Signal Acquisition Control

The GCFE ASIC shall capture and readout event amplitudes under the control of an external acquisition control timing signal. The external timing shall control the capture of the peak pulse amplitude in the T&Hs, the range selection and readout of the range and crystal accept bits, the selection and readout of sequential ranges, and the final reset of the ASIC to idle, tracking configuration. The timing of this sequence shall be controlled with the external signal; the control logic and decision making shall be internal to the ASIC.

9.1.15 Performance Requirements

The following requirements apply to the signal acquisition by the charge amplifiers, through the shaping amplifiers, track and holds, analog multiplexer and buffer amplifier.

9.1.15.1 Low Energy Equivalent Noise

The equivalent noise (RMS) on the low energy slow shaped signal paths (LEX8, LEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the low energy fast shaped signal path (FLE) shall be less than 3000 e^-.

9.1.15.2 High Energy Equivalent Noise

The equivalent noise (RMS) on the high energy slow shaped signal paths (HEX8, HEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the high energy fast shaped signal path (FHE) shall be less than 10000 e^-.

9.1.15.3 Integral Linearity

The output of the buffer amplifier for each of the four amplifier ranges shall be monotonically increasing with charge input over the top 99.9% of the energy range. The integral non-linearity shall be less than ±0.5% of full scale. This is the deviation of the best fit straight line from the measured amplitudes over the top 99% of the energy range. (Same as 9.1.5, just stated differently)

9.1.15.4 Single Range Processing Deadtime

The signal acquisition and processing time for a single energy range shall be less than 100 μsec. The goal shall be 20 μsec.

9.1.16 Environmental Requirements

9.1.16.1 Operating Temperature Range

The performance specifications of the GCFE ASIC shall be achieved over the operational temperature range (see para 8.1).

9.1.16.2 Storage Temperature Range

The GCFE ASIC shall be capable of meeting its performance specifications after indefinite storage in the temperature range (see para 8.1).

9.1.16.3 Qualification Temperature Range

The performance of the ASIC shall be tested over the qualification temperature range of –30 to +50 degrees C. It shall survive testing over this range and meet performance specifications when returned to the operational temperature range(see para 8.1).9.1.16.4Radiation Single Event Latchup

The GCFE ASIC shall be insensitive to latchup for LETs < 8 MeV/(mg/cm^2).

9.1.16.5 Radiation Total Dose

The GCFE ASIC shall meet its performance specifications after a total radiation dose of 10 kRad.

9.1.17 Mechanical Requirements

9.1.17.1 Mounting

The GCFE ASIC shall be mounted in a quad flatpack carrier with square footprint of size < 15 mm (TBR).

9.1.17.2 Height

The GCFE carrier height shall be less than or equal to 3 mm.

9.1.18 Power

The GCFE ASIC power consumption shall be less than 6 mW per CsI crystal end.

9.2 ADC

The ADC needed for the calorimeter readout needs to be small, fast, low power and of relatively good resolution.

9.2.1.1 Number of Bits

The ADC shall be a 12 bit ADC.

9.2.1.2 Differential Non-Linearity

The average differential non-linearity of the ADC shall be less than 0.25 least significant bit.

9.2.1.3 Integral Non-Linearity

The maximum non-linearity of the ADC shall be 0.5 % of full range.

9.2.1.4 Speed

The ADC shall perform a full conversion in less than 10 microseconds for all input values.

9.2.1.5 Input Voltage Range

The ADC shall convert signals between 0 and an applied reference voltage. The applied reference voltage shall be between 2.0 and 3.0 Volts.

9.2.1.6 Power

The ADC shall use less than 5 mW in quiescent mode and less than 8 mW during conversions.

9.2.1.7 Mechanical Dimensions

The ADC shall not be taller than 3 mm, and its footprint shall be less than 13mm by 13 mm.

9.2.1.8 ADC Power Voltage

The ADC shall operate at a voltage of 3.3 Volts.

9.3 GCRC

The dead time associated with the capture and measurement of the energy depositions shall be less than 20 µsec. (Nothing else for GCRC??)

9.4 AFEE Boards

Each of the four individual AFEE boards per calorimeter module handles the front-end electronics of the crystal ends facing it.

9.4.1 Functionality

Each boards shall hold the GCFEs, ADCs, GCRCs, a DAC (digital to analog converter, for calibrations), a temperature sensor and all these components' associated electronics. The AFEE boards shall also support whatever additional electronics or sensors are deemed necessary in the location of the AFEE boards.

9.4.2 Types of AFEE Boards

There shall be two types of AFEE boards, named X-boards and Y boards, for the direction of the crystals they service. The two X (Y) boards are then separated in to a –X (-Y) and + X (+Y) board, depending on which side of the calorimeter they service. The +X and –X boards shall be identical except for a hardwired control (jumper) that selects whether a board services the + or – face. The same rule applies for the Y boards.

9.4.3 Channel Numbers and Layout

Each AFEE board shall service 48 crystal ends. These crystal ends are arranged in 4 layers of 12 crystals. The crystal pitch is ~ 28 mm, the layer pitch is ~ 42 mm. The AFEE layout shall minimize the connection distance between the PIN diode and the GCFE. The – X and -Y boards shall have the channel number within a row increasing from right to left, the +X and +Y boards shall have the channel number within a row increasing from left to right. Left and right are determined by looking from the outside of a board with the Z-axis pointed up.

9.4.4 PIN Diode Interface

Each crystal end shall connect to the GCFE with a polyimide cable fed through a hole in the AFEE board. The hole for the polyimide cable shall be at least 8 mm by 2mm. A bending radius of 1 mm is allowed in the corners of the holes. The polyimide cable shall be connected to the AFEE board using a space qualified connection.

9.4.5 Operating Voltages

Each AFEE board is provided with two voltages: one 3.3V voltage to operate the AFEE board itself, and one high voltage in the negative 50-100 Volt range to bias the PIN diodes. The regulations of these voltages shall not happen on these boards, but the boards shall filter these voltages appropriately. (LAT-SS-00183)

9.4.6 TEM Electrical Interfaces

The AFEE board shall communicate to the Tower Electronics Module (TEM) through Low Voltage Differential Signaling (LVDS). No common ground shall span the connection.

9.4.7 Mechanical Dimensions

Each AFEE board shall have maximum dimensions of 341 mm by 341 mm. The maximum thickness of the board shall be 2 mm. The maximum thickness of the board and its components shall be 8 mm. No component shall be raised more than 3 mm from either surface of the board.

9.4.8 Mechanical Interfaces

Each AFEE board shall be supported around its perimeter and with posts traversing the board.

There shall be 10 posts passing through the board in rows of 2 or 3 posts. The rows of posts shall be located half way between the rows of PIN diode interface holes. The diameter of the hole in the AFEE boards for the posts shall be TBD mm. No component shall be located within TBD mm of the hole. No trace on the board shall be within TBD mm of the hole.

No component shall be located within TBD mm of the outside perimeter of the AFEE board. No trace on the board shall be within TBD mm of the perimeter of the board.

9.4.9 Power

Each AFEE board shall not use more than 1.25 Watts of the 3.3V voltage line.

Each AFEE board shall not use more than 0.001 Watts of the 50-100 V voltage line.

9.4.10 Thermal Requirements

9.4.10.1 Operating Temperature Range

The performance specifications of the AFEE shall be achieved over the operational temperature range of –10 to +35 degrees C.

9.4.10.2 Storage Temperature Range

The AFEE shall be capable meeting its performance specifications after indefinite storage in the temperature range of –20 to +40 degrees C.

9.4.10.3 Qualification Temperature Range

The performance of the AFEE shall be tested over the qualification temperature range of –30 to +50 degrees C. It shall survive testing over this range and meet performance specifications when returned to the operational temperature range.

9.4.11 Grounding

The AFEE board shall be grounded to the calorimeter structure per LAT document LAT-SS-00272-D1, LAT Grounding and Shielding Plan.

9.4.12 AFEE Failure

Each AFEE board shall be constructed such that an electrical or electronic failure of one board does not affect any of the other three boards of the same calorimeter module, or the two provided voltages.

9.4.13 Coating

Each AFEE board shall be coated with conformal coating per specification TBD.

9.5 High Energy Trigger Signal

The calorimeter shall provide a prompt (within 2 μs of an event) high-energy trigger signal with a detection efficiency of 90% (TBR) for 20 GeV gamma rays entering the calorimeter from the LAT field of view that deposit at least 10 GeV in the CsI of the calorimeter.

9.6 CAL Module to T&DF Interface

The AFEE shall interface to the T&DF system using flexible printed circuit cables which attach the AFEE to the TEM mounted on the CAL baseplate. A separate cable shall attach the AFEE to the power system also mounted on the CAL baseplate. (TBR).

10 Data System

The Calorimeter Data System functionality shall reside in the Calorimeter Controller, located in the Tower Electronics Module.

This functionality and the CAL AFEE to TEM interface requirements are specified in LAT-SS-00467.

11 Environment

11.1 Launch Environment Loads

All components shall be designed to withstand the induced static, random vibration and acoustic loads associated with a Delta II launch environment. These loads are defined in section 6.1 of the LAT MPS document and are derived from the Delta II LV Payload Planner's Guide.

11.2 Launch Pressure Profile

All components shall be designed to withstand the pressure profile associated with the Delta II launch. This profile is defined in Figure 6.7-1 of the LAT MPS document and is derived from the Delta II LV Payload Planner's Guide

11.3 Component Environment

The CAL components shall be designed to operate in a low Earth orbit environment

11.4 Sub-System Environment

The instrument sub-systems shall be designed to operate in a low Earth orbit environment

11.5 SEE Immunity

Critical systems shall be immune to SEEs. Critical systems are those that can cause permanent loss of mission in the event of a single failure

11.6 Minimum Power Up Temperature

All electronics shall be able to power up from an initial temperature of – -30 (TBR)°C and subsequently transition into their other operational modes/states.

12 Operational Modes

The Calorimeter shall provide the functionality required for the SI to perform operations in the sky survey, pointed observation and safe modes of operation. These specific requirements can be found in the GLAST Mission System Specification (MSS), Section 3.1.15, Modes of Operation. The Calorimeter shall meet the load shedding requirements of the fault protection functions on the spacecraft that are identified in the SI/SC IRD, Section 3.2.7, Fault Protection.

13 Ground Support Equipment

13.1 Stand-Alone Testing

CAL modules shall have ground-support equipment that will allow for stand-alone operation, test and data analysis.

13.2 Simulators

CAL module GSE shall be supported by TEM and T&DF simulators provided by the T&DF subsystem designers.

13.3 Computer and Network

Workstations or personal computers associated and provided with the cal subsystem shall have Ethernet connectivity with appropriate software to share data files and electronic messages with other nodes on the I&T local area network

13.4 Pre-Integration Testing

All module components shall undergo functional, environmental and interface testing prior to module integration and test in order to verify their individual functional and performance requirements

14 Integration and Test

14.1 Integration and Test Temperature Range

The Calorimeter shall be capable of tolerating temperatures of 20-25°C in air, in any operational mode. This is the expected temperature range of the controlled environment in the integration and test facilities.

14.2 Integration and Test Relative Humidity

The Calorimeter shall be capable of tolerating relative humidity in the range 35%-50%, in any operational mode. This is the expected humidity range of the controlled environment in the integration and test facilities.

15 VERIFICATION STRATEGY

The verification strategy will test, analyze (may include modeling/simulation), inspect, or demonstrate all requirements of section 5 to ensure that the instrument meets its specified requirement. The matrix below indicates the methods of verification employed to verify the science performance.

Table 15-1. Requirements Verification Matrix

PLEASE REFER TO CAL VERIFICATION MATRIX LAT-SS-000XXX